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by

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INJURY THRESHOLD OF CORNEA TO CO_2 LASER LIGHT EXPOSURE

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ABSTRACT

The minimum visible lesion in the corneal epithelium resulting from exposure to CO_2 laser light is carefully determined. the dose causing 50% probability of damage (ED_{50}) varied with time of exposure. For 1.03 seconds it was 7.52 W/cm^2 (95% CL 5.8~5.85 W/cm^2) and for 0.12 seconds it was 10.7 W/cm^2 (95% CL 10.4~10.9W/cm^2)

CO_2 lasers are currently one of the most widely used lasers in industry, scientific research, medicine and the military. This paper studies the relationship between different exposure times and different exposure dosages of continuous wave CO_2 laser light and the incidence of cornea injury. From this, it finds the injury threshold.

I. Experiment

This experiment used a CO_2 laser for irradiation equipment, a power attenuator, a timer and a measuring device, a monitor power meter, a He-Ne laser, a limited aperture shutter and an animal exposure platform as shown in Figures 1 and 2. The maximum output was 20W. The output stability was within $\pm$3%1, almost level, and the angle of dispersion was 2.5mrad.

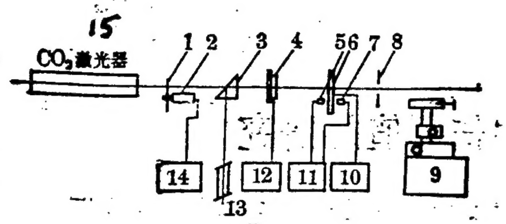
The exposure time was measured to a precision of better than

0.5%. There were two different exposure time groups. One group averaged 1.03 seconds and the other 0.12 seconds. The time measurement standard error coefficients were <±15 and <±5%. The laser power measurement standard error coefficient was <±5%.

The animals used in the experiment were chinchilla rabbits weighing between 2.4 and 3.7 kilograms. Prior to exposure they were examined with a slit-lamp microscope and found to be normal. During exposure the rabbits were placed on a table adjustable in three directions. A one millimeter diameter aperture was placed in front of their eyes to restrict the beam, and a He-Ne laser was used along the same light axis for alignment. Within ten minutes after exposure they were again examined with a slit-lamp microscope and the findings checked by two or more people. A total of 142 rabbit eyes were used in the experiment, with 354 exposure points. These were split up into 11 dosage groups. Groups one through six were exposed for an average of 1.03 seconds, and groups seven through eleven were exposed for an average of 0.12 seconds.

Fig. 1 Exposure equipment

Fig. 2 Optical circuit diagram of exposure equipment



1. Stainless steel mesh. 2. DC motor. 3. Right angle prism. 4. Pass through power meter. 5. Light source. 6. Electromechanical high speed shutter. 7. Photoelectric cell. 8. Aperture. 9. Animal exposure platform. 10. Timer. 11. Time measurement. 12. 1503 digital clock. 13. He-Ne laser. 14. Power source. 15. CO_2 laser.

II. Results

1. Indications of corneal injury: The range of radiation dosage used in this experiment averaged a power density of 4.16~13.4 W/cm², and the injuries caused were all slight and shallow, localized on the upper layer of the cornea. Under a slit-lamp there was no round gray-white or light gray injury spot. The lesser injuries were light gray spots or quarter moon shaped with a white dot in the middle. The injury spots generally receded 16 to 24 hours after exposure, and the gray-white injury spots were markedly improved after 48 to 72 hours, with the appearance of a thin veil.

2. Relationship between exposure dosage, exposure time and incidence of corneal injury. Under the conditions of the experiment - the incidence of corneal injury within the 11 experimental groups with different exposure dosages and different exposure times is shown in Table 1. We can see from this table that the incidence of corneal damage increases as the power density rises, and the amount of radiation dosage required for the same incidence of injury is less as exposure time is increased.

Tab. 1 Relationship between CO_2 laser exposure dosage, exposure time and incidence of corneal injury

1 实验分组	2 平均照射时间(s)	3 照射剂量		6 损伤发生率	
		4 平均能量密度 (J/cm²)	5 平均功率密度 (W/cm²)	7 损伤数/样点数	8 百分率
1	1.0463	8.32	7.95	50/50	100
2	1.0251	7.07	6.89	61/66	92.4
3	1.0240	6.62	6.47	70/82	85.4
4	1.0233	6.04	5.90	25/50	50.0
5	1.0215	5.50	5.39	26/72	36.1
6	1.0232	4.27	4.17	2/102	1.96
7	0.1209	1.62	13.4	62/70	88.6
8	0.1218	1.45	12.0	47/60	78.3
9	0.1211	1.31	10.9	34/60	56.7
10	0.1219	1.24	10.1	68/192	35.4
11	0.1280	0.972	7.59	4/50	8.0

1. Experimental group. 2. Average exposure time (seconds). 3. Exposure dosage. 4. Average energy density (J/cm²). 5. Average power density (W/cm²). 6. Incidence of injury. 7. Number of injuries/number of test points. 8. Percentage.

3. Calculation of the corneal injury threshold: The ED_{50} of CO_2 laser light corneal injury threshold usually refers to the required radiation dosage required for a 50 percent probability visible injury to the cornea upon slit-lamp microscopic inspection within ten minutes following exposure. Based on the results of the experiment, we have:

When exposure time averaged 1.03 seconds, the regression equation is:

$$\hat{Y} = 1.66x - 7.661$$

$$ED_{50} = 5.72\ W/cm^2$$

(95 percent confidence limit 10.4~10.9W/cm²)

When exposure time averaged 0.12 seconds, the regression equation is:

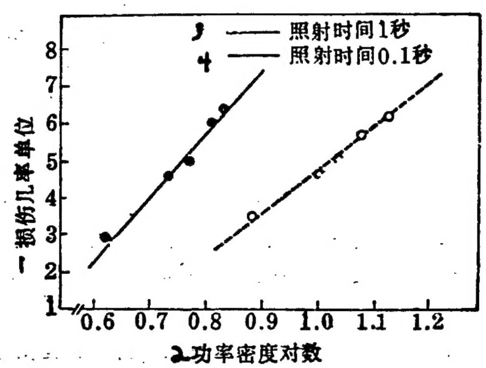
$$\hat{Y} = 11.77x - 7.087$$

$$ED_{50} \sim 10.7W/cm^2$$

(95 percent confidence limit is 10.4~10.9 W/cm^2)

The regression graphs of the CO^2 laser radiation dosage, exposure time and incidence of corneal injury are shown in Figure 3.

Fig. 3. Relationship between the CO_2 laser radiation dosage, exposure time and the incidence of corneal injury



1. Injury probability units. 2. Coefficient of power density. 3. Dotted line is exposure time of one second. 4. Solid line is exposure time of 0.1 second.

III. Pathological histology examination of the injuries

Pathological histology examination of 28 rabbit eyes indicated that within this radiation dosage range, the basic pathologic change was coagulation on the top skin of the cornea, edema and necrosis. A typical injury could be divided into three zones:

1. Central necrosis zone: In the middle of the corneal burn, edema and necrosis occurred in the cells, with exfoliation and forming localized lesions of the upper skin. The size of the lesions and their locations differed, with most of them in the

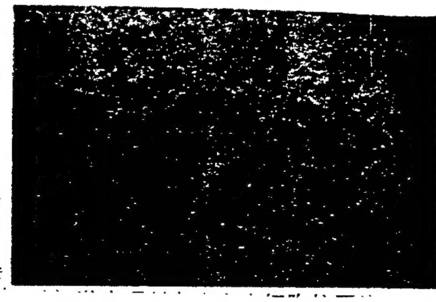
lesions and their locations differed, with most of them in the center of the injury, but there were also some to one side. This may be connected to inconstancy in the "hot point" distribution of the CO_2 laser. Where the necrosis was relatively sever, the entire upper skin exfoliated to form a flat bottomed or pointed depression. Where the necrosis was relatively slight, the upper skin cells exfoliated to form a bump on this layer. There were no obvious changes in the stromal layer.

2. Surrounding coagulation zone: As the intensity of the laser light beam on the surround areas was reduced, the injuries gradually lessened. The pathologic changes surrounding the necrosis zone was primarily cell coagulation, with karyopyknosis, hyperchromatic and karyoklasis.

3. The peripheral edema and coagulation zone: Edema or coagulation occurred in the shallow flat or wing-shaped cells of the peripheral corneal skin surrounding the injury, and there was karyopyknosis.

These typical indications differed in degree of injury with different amounts of radiation. The more severe injuries were larger, and there was more exfoliation. In the less severe cases, there was no necrosis or pathologic change, but only coagulation of the upper skin as shown in Figure 4. The extremely slight injuries were small and shallow, only having slight swelling and coagulation in the shallow cells. Some injuries were like a shallow dish, 200 to 300μm in diameter. Injuries near the radiation dosage threshold were mostly slight or extremely slight.

Fig. 4 Cornea surface cell Karyopycnosis and surface flaking from CO_2 laser exposure



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Bibliography: (omitted).